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National Aeronautics and Space Administration
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Attention:	T. L. K. Smull, Director Grants and Research Contracts Office of Space Sciences
Subject:	Fourth Semi-Annual Progress Report
Reporting Period	1 November 1964 to 30 April 1965
Contract Title:	Study of Antenna Problems Associated with Space Vehicles
Contract No.	Grant NsG 444
Contract Monitor	W. F. Croswell, CRS/IRD Langley Research Center

Distribution

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The principal effort under the subject grant during the period 1 November 1964 to 30 April 1965 has been applied in further investigation of the synthesis problem for an infinite cylindrical conductor with one or more surface slots in which a transverse electric or magnetic field is excited.

The integral expression which relates the far field of the cylinder to the field at the surface, analogous to the finite Fourier transform relationship holding in the case of a plane aperture or line source, was detailed in the last semi-annual report. This relation is studied further in an internal memo which is listed at the end of this report, and the areas of similarity and dissimilarity between the plane and cylindrical cases are more clearly delineated. In particular, it is established that the completeness relation which holds in the plane case is also valid for the cylindrical case, i.e. any far-field pattern in the azimuth plane which is square-integrable over the entire real space, $-\pi < \phi \leq \pi$, can be approximated arbitrarily closely by means of a surface field which is square-integrable over an aperture of arbitrary angular width and vanishes outside this aperture. As in the plane case, however, unless the given pattern function belongs to a special subclass, the required aperture function becomes more and more ill-behaved as the approximation is improved, so that any realistic analysis of the problem must involve some sort of constraint on this behavior, which in general will relate to the energy stored in the near field. Several possible forms of this constraint have been examined and compared, and an optimization procedure has been developed for the single-aperture problem. The technique consists of minimizing the mean-square deviation from a given far-field pattern with an aperture function expressible in terms of a finite set of basis functions and having a fixed value of the stored energy. It is found that if the stored energy is to be finite, the basis functions must satisfy the Meixner edge condition at the

ends of the aperture. A computation program is being prepared which utilizes the most restrictive of the constraints examined, namely the quality factor defined by Collin and Rothschild*, which is proportional to the ratio of the larger of the time-averaged electric or magnetic energies stored in the evanescent field to the radiated power. Numerical results given by this procedure should be available in the near future.

The computations mentioned in the preceding progress report, based on a simpler optimization problem, where the only restriction imposed on the aperture field is that it shall be expressed as a trigonometric polynomial of fixed degree, are now substantially completed. Several types of prescribed patterns have been treated, including omnidirectional and essentially sectoral forms, and the dependence of actual pattern and mean-square error on beam width, aperture width, and cylinder diameter have been examined. Analysis of these results is not yet complete, but certain conclusions are immediately indicated. Perhaps the most important of these is that if the amplitude or power pattern is of primary interest, the minimization of the mean-square error is not, in general, a satisfactory mode of solution for the synthesis problem in the cylindrical case. Whereas in the plane case this process yields a real pattern if the prescribed pattern is real, the same does not hold for the cylinder. Here the process always yields a complex pattern whose phase may vary widely and whose amplitude may be well below that of the prescribed pattern over most of the angular range.

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* Collin, R. E. and S. Rothschild (1963) "Reactive Energy in Aperture Fields and Aperture Q," Can. J. Phys., 41, No. 12, pp 1967-1979.

In an effort to improve the amplitude synthesis, an iterative scheme has been developed, wherein at each step the phase of the prescribed pattern is modified by a factor given by the minimization of the mean-square error ϵ_N in the preceding step. This process can be shown to reduce the value of ϵ_N at each step, and must, therefore, converge to a function whose amplitude is a better approximation to that of the prescribed pattern than that obtained via the simple minimization procedure. Whether this can be represented as a general method for power pattern synthesis is not yet established, but the investigation is continuing and a computational program is nearly complete.

A study of several types of arrays of slots on the infinite cylinder has been completed, including fairly extensive computations. In all cases the slots were one half wavelength long and of infinitesimal width. Three types of array were considered, one consisting only of axial slots, one of only circumferential, and one of alternating axial and circumferential. For the first two types it was determined that the minimum mean square error between the actual far-field pattern and a uniform (omnidirectional) pattern was achieved by taking the amplitudes and phases of the feeding voltages equal for all slots, and these voltages and the resulting minimum errors were computed as functions of the number of slots and the cylinder diameter. As in the case of a single slot, it was found that the minimization of the mean square error is not in general an effective means of synthesizing a uniform power pattern. The alternating array was shown to be capable of producing a far-field pattern with prescribed elliptical polarization, provided the amplitude is sufficiently uniform.

A technical report containing all results obtained to date on the synthesis problem is in preparation and will be issued soon.

The work in the field of radiation phenomena in moving media will soon be shifted to a new grant awarded by NASA to the Radiation Laboratory and starting 1 May.

During the period covered here, the following results have been obtained:

1) A closed form of the dyadic Green's function for moving media has been derived. This work is published in the correspondence section of the IEEE Trans. -PGAP (see bibliography below).
2) A paper on Huygen's principle for moving media was presented at the Instituto Tecnologico de Aeronautica in Brazil. The manuscript has also been accepted for publication in Applied Optics.
3) A diagnostic presentation of various indefinite forms of Maxwell's equations in moving media has been completed.

In a new direction, a study has been begun in connection with the problem of the degradation of azimuthal antenna patterns due to the coating on a space vehicle (see Memo 05780-513-M, listed below). The immediate objective of the investigation is to determine the surface current on a dielectric-coated conducting cylinder due to a local electric field excitation which is compatible with the assumption of a recessed slot. Once this relation is known it should be possible to decide whether the feeding region can be so designed and excited that a standing wave structure of the surface current is avoided and the side lobes of the pattern, i.e. in the axial direction, are thus suppressed. Since the standing wave structure can be decomposed into pairs of traveling waves going in opposite directions, but otherwise similar in form, it should be possible to obtain at least a qualitative idea of the situation by examining a single traveling wave on an infinite cylinder. This can be accomplished by means of a Fourier transform technique that gives the solution in terms of a contour integral in the complex plane.

The following bibliography lists all technical literature which has originated under the subject grant, or whose publication status has changed since the last progress report.

Memos:

"Meeting with the Contract Monitor for Project 5780 on 2 December 1964," F. Sleator, C-T. Tai, and P. Uslenghi. Radiation Laboratory Memo No. 05780-513-M, 11 December 1964.

"Radiation Pattern Synthesis," O. Einarsson. Radiation Laboratory Memo No. 5780-514-M, 22 January 1965.

Reports:

"The Pattern Synthesis Problem for a Slotted Infinite Cylinder," O. Einarsson, F. Sleator, and P. Uslenghi. Radiation Laboratory Technical Report No. 05780-4-T, in preparation.

"Application of Conformal Mapping to Scattering and Diffraction Problems," S. Hong. Radiation Laboratory Technical Report No. 05780-5-T, completed and to appear soon.

Articles:

"High Frequency Scattering from a Coated Cylinder," P. Uslenghi, Can. Journ. Phys, 42, (Nov. 1964) pp 2121-2128.

"A Note on Dielectric Lenses," P. Uslenghi, Can. Journ. Phys., 42, (Nov. 1964) pp 2359-2364.

"The Backscattering Radar Cross Section of Long Thin Dielectric Bodies of Revolution on a Metal Plane," P. Uslenghi, (to be published) Can. Journ. Phys., 43 (1965).

"Diffraction of a Dipole Field by a Conical Ring," P. Uslenghi, (to be published) Applied Sci. Res., Sect. B (1965).

"On the Synthesis Problem for an Infinite Cylinder with an Axial Slot," O. Einarsson and F. Sleator, accepted for presentation at URSI Symposium in Delft, September 1965.

"Application of Conformal Mapping to Diffraction and Scattering Problems," S. Hong and R. Goodrich, accepted for presentation at URSI Symposium in Delft, September 1965.

"Two Boundary Value Problems Involving Moving Media," C-T. Tai. Presented at URSI Washington Meeting, April 1965.

"Huygen's Principle in a Moving Isotropic Homogeneous and Linear Medium,". C-T. Tai. Presented at the First National Electronics Conference at Instituto Tecnologico de Aeronautica, Brazil, January 1965. Also accepted for publication in Applied Optics.

"The Dyadic Green's Function for a Moving Isotropic Medium," C-T. Tai, IEEE Trans. -PGAP, 13, (March 1965) pp 322-323.

"Electrodynamics of Moving Anisotropic Media: The First-Order Theory," C-T. Tai, N. B. S. J. Res. D., Radio Science, 69D, No. 3, (March 1965) pp 401-405.

F. B. Sleator